RESEARCH BULLETIN

Sustaining perennial horticultural production under supplementary irrigation drawn from saline groundwater

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Introduction

Supplementary irrigation can be distinguished from "full" irrigation based on the major source of water for crop evapotranspiration. Under supplementary irrigation, rainfall is the major source of water. Although irrigation is the minor source of water, when saline, it represents the major source of salt.

Groundwater is currently used to supply supplementary irrigation in about half of Australia's vineyards. The salinity of groundwater in many basins is rising; for example in the Padthaway region in South East of South Australia the salinity has risen by about 1dS/m over the past 3 decades. Use of this water for irrigation is causing salinity damage to vines. Severe salinity damage can cause destruction of the vine canopy, which prevents the crop reaching maturity. Mild damage can increase the salt concentration in grape juice, which increases the potential for wines to display a salty character. Saltiness is a taste associated with an elevated levels of sodium in the juice.

This project addresses these issues through investigating: the redistribution of rain falling in the mid row toward the saline soils located under the vine; salt exclusion properties of rootstock vines which were planted over two decades ago; the linkage between levels of sodium and chloride in vine tissue and readily acquired measures of soil salinity.

Field studies included use of plastic sheets to divert rain water

Re-distributing rain to manage saline irrigation

Viticultural production in the South East of South Australia developed using groundwater for supplementary irrigation. Early irrigation methods of over-canopy sprays or flood have been replaced by drip irrigation. This change has been associated with a reduction in annual irrigation depths. If water salinity remained constant, then this reduction would also reduce the annual addition of salt via irrigation water. Rising groundwater salinity has diminished this effect. The effects of changes in irrigation volume and salinity have been analysed using one dimensional modelling of vineyard water and salt flows. The model predicted that these changes should not raise the steady state values of soil salinity above the threshold for vine damage, however reports of salinity damage to vines are becoming more prevalent. Soil salinisation is a complex process and models of this process make many assumptions. The one dimensional model assumes that the soil salt is spread evenly across the vineyard. We tested whether this assumption applied in three salt affected vineyards in the Padthaway area by measuring the spatial distribution of salt in soils after harvest.

In all three vineyards we found that the levels of salt in leaf samples collected after harvest were well above values usually indicative of yield loss caused by salinity, that is a sodium at concentrations greater than 0.6% and chloride greater than 0.8% (Stevens, 2005). The soils sampled post-harvest from within 20 cm of vine row, to a depth of 50 cm were saline and sodic with an average EC_e of 7.7 dS/m and SAR_e of 13 (Figure 1). This salinity is well above the suggested 1.8 dS/m threshold for yield loss.

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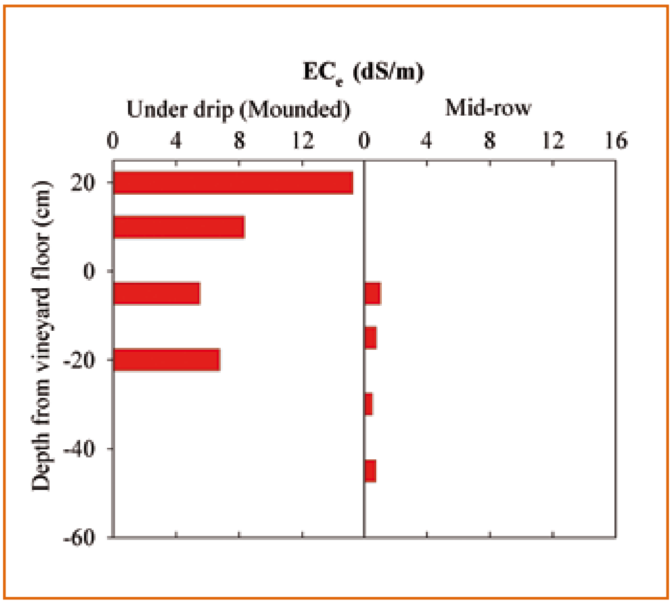


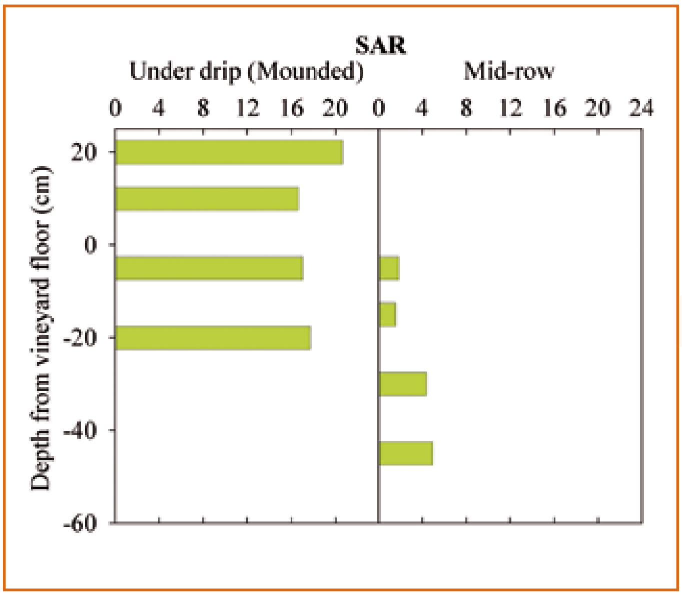


Figure 1. EC$_e$ and SAR (sodicity) at mounded vineyard on Padthaway Flat, April 2009.

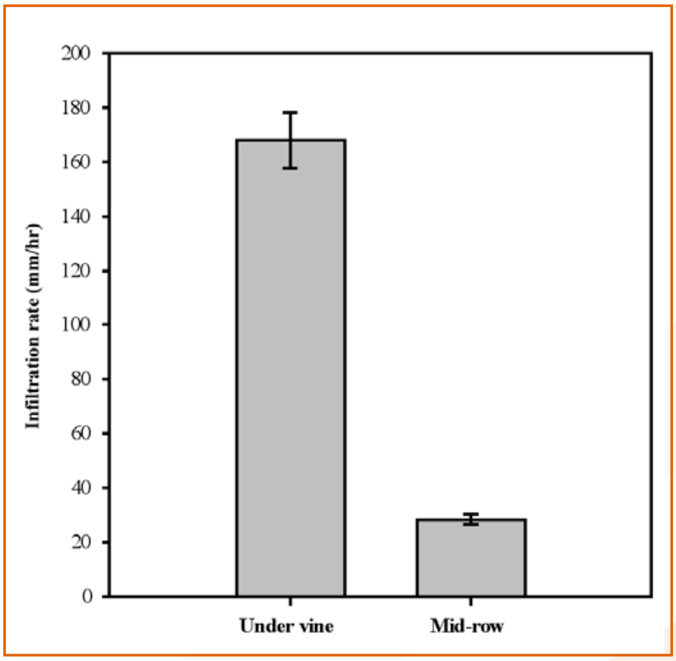


Figure 2. Infiltration rate of rain water in under-vine and mid-row soils of a mounded Chardonnay vineyard

In contrast, soils sampled in the mid-row, to a depth of 50 cm, were non-saline and not sodic with an average EC$_e$ of 0.6 dS/m and SAR$_e$ of 3 (Figure 1). These results show that the assumption that soil salt is spread evenly across the vineyard does not apply in this situation.

In addition to being saline, the soils under the vine were also sodic. Sodicity can reduce rainfall infiltration. Under supplementary irrigation, rainfall is the major source of water flushing salts from the rootzone. We tested whether sodicity was preventing rainfall percolation by measuring infiltration rates with a Cornell Sprinkler Infiltrometer. We found that infiltration rates under the vine were higher than those in the mid-row (Figure 2). This indicated that under-vine sub soil sodicity did not prevent percolation of rain. This was confirmed by post winter soil sampling which showed that soil salinity, but not sodicity had declined over winter.

Winter rain at the Padthaway site leached salts applied during the previous irrigation season. It reduced the salt content of both the saline soils under the vine and the non-saline soils in the mid-row. However the season opened with under vine soils still saline, albeit at levels less than in previous autumn. We hypothesised that re-distributing rain falling on the mid row to under vine would improve the chance of opening the season with non-saline soils.

At the start of 2010 we established a "proof of concept" field trial to test whether soil and vine salinity could be reduced by redirecting the rain falling in the mid-row toward the saline soils located under the vine. Six treatments were developed (Figure 3). Treatments were designed to test the response of leaching to:

1. an increase in the amount of rain percolating under the vine through the re-direction of rain falling in the mid-row (treatment (E&F);
2. a reduction in evaporation of water from the soil surface in the mid row (treatment D, E & F);
3. a reduction in the evaporation of water from the soil surface under the vine through enhancement of water percolation through the sub soils by reducing sodicity (treatment C & F);
4. a reduction in the evaporation of water from the soil surface under the vine through removal of the under vine mound (treatment B).

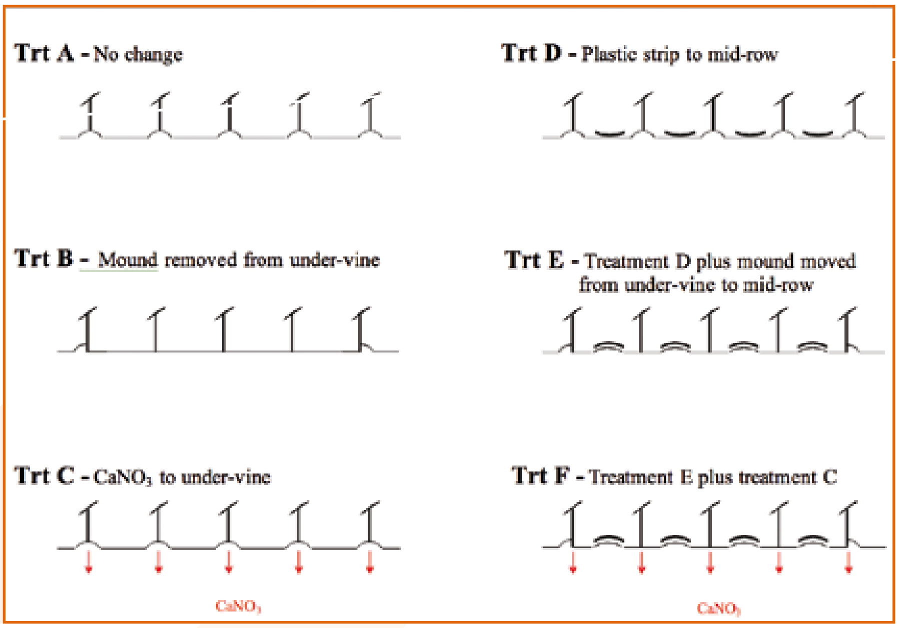


Figure 3. Treatments to test the effect of redirecting rain from mid-row to under-vine soil upon soil and vine salinity

Treatments were installed just prior to harvest 2010. They were laid out as two Latin squares, each being six treatments by six replicates. A plot consisted of 5 rows of 4 vines each with soil and vine samples taken from the middle two vines in the middle row. Pre and post irrigation season soil sampling together with plant tissue analysis will be used to identify effects. Vine canopy area will be used as a co-variate to remove treatment induced variations in the rates of vine transpiration.

In April 2010, soil samples were collected from all treatment plots. Since installation of treatments late January, 84mm of rain had fallen. Samples from 30-40 cm deep (just above the limestone layer) have been analysed for pH and electrical conductivity (EC). There was no significant treatment effect on soil pH1:5 with an average $pH_{1:5}$ of 8.35. Treatments were, however, already affecting soil salinity. The $EC_{1:5}$ of both treatments E and F, plastic covered mid-row mounds, were lower than that in treatment A ,the control.

Salt exclusion in vines planted on rootstocks over two decades ago

The viticultural industry uses rootstocks to impart a level of resistance to soil-borne pathogens such as phylloxera and nematodes (Dry, 2007). Research on young vines has also shown that rootstocks can provide tolerance to salinity stress (Walker et al. 2002). Given that salinity is an emerging issue for some Limestone Coast vineyards and that spread of phylloxera into the district is an ever present risk, there is a need to identify rootstocks that can address both issues.

Various research bodies, including SARDI, are investigating rootstocks to answer this need. However, all published data to date relates to young plantings. SARDI have an opportunity to revisit Limestone Coast rootstock trials, planted by the SA Agriculture Department, in the early to mid 1980's. The current condition of these rootstock trials will reveal the performance of rootstock vines grown under commercial viticultural practices for more than two decades. These investigations aim to identify the stability of salinity resistance over time. Results will give grape growers greater confidence in the selection of rootstocks that will deliver long-term productivity with both phylloxera and salinity tolerance.

In 2009, SARDI revisited two rootstock trials, for Chardonnay and Shiraz vines, in the Limestone Coast. Chardonnay fruit was sampled in the 2009 season and both trials were sampled in 2010.

Both rootstock and season affected juice sodium concentration in the Chardonnay rootstock trial, and rootstock effect was modified by season (Table 1). The geometric means of sodium concentration in 2009 and 2010 seasons were 66 and 23 mg/L. Fruit in the 2009 season was more mature than that in 2010 (26 versus 21 °Brix). In 2009, Ramsey had the highest sodium concentration. It was above that in juice from own rooted vines. In 2010, the highest sodium concentrations were in juice from own rooted vines and vines on Freedom.

Table 1. The effect of rootstock and season on the concentrations of sodium and chloride in Chardonnay grape juice. For within element comparisons the values followed by different letters are significantly different from each other (P=0.05).

	Rootstock								
Year	K51-32	Fercal	Schwarzmann	Ramsey	SO4	K51-40	Teleki 5C	Own roots	Freedom
	Juice Sodium (mg/L)*								
2009	36.2^{d}	49.3^{c}	47.6^{c}	143.2^{a}	45.7^{c}	90.5^{b}	49.7^{c}	94.6^{b}	104.9^{b}
2010	21.5^{f}	18.3^{fg}	16.3^{g}	28.8^{e}	9.4^{h}	25.5^{ef}	20.6^{f}	46.7^{c}	42.8^{cd}
	Juice Chloride (mg/L)								
	37.1^{c}	37.7^{c}	29.0^{c}	26.6^{c}	28.7^{c}	149.3^{a}	30.0^{c}	67.3^{b}	31.2^{c}

** Sodium data was $\log_e$ transformed for analysis and the values in the table are the geometric means.*

The effect of rootstock on juice chloride concentration at the Chardonnay site was not modified by season. The means of chloride concentrations in 2009 and 2010 were 52 and 45 mg/L. High concentrations of chloride were present in juice from own rooted vines and vines on K51-40.

Amongst the stocks assessed at the Chardonnay site, only SO4 is rated as having very high resistance to phylloxera (Hardie and Cirami 1988). Its ability to exclude sodium equalled or bettered that of Schwarzmann and its ability to exclude chloride equalled that of Ramsey.

At the Shiraz rootstock trial, comparison between vines in their 6th and 24th year shows that yield was not affected by aging except for vines on Petit Verdo (Figure 4). The absence of an effect of aging on the performance of vines on 101-14 contrasts with the findings of Walker et al (2010). They found that the yield of Shiraz on 101-14 growing on saline soils (EC_e 2.9 dS/m) near Mildura declined between 4th and 21st year. Their vines were irrigated with water of 2.1 dS/m, however the role of salinity in this decline is unclear because the leaf and fruit levels of Na and Cl were not elevated in vines on 101-14. The salinity of irrigation water at the SARDI rootstock trial is about 1.5 dS/m. At a vineyard with saline soils (EC_e 4.2 dS/m), but receiving non-saline irrigation (EC_w 0.4 dS/m), Stevens et al (2010) found that 8 year old Shiraz on 101-14 out yielded vines on seven other rootstocks including Ramsey, 1103 Paulsen and 140 Ruggeri. Combining this observation with that in the present trial supports a contention that Shiraz on 101-14 can perform well at saline sites and can sustain this performance under saline irrigation.

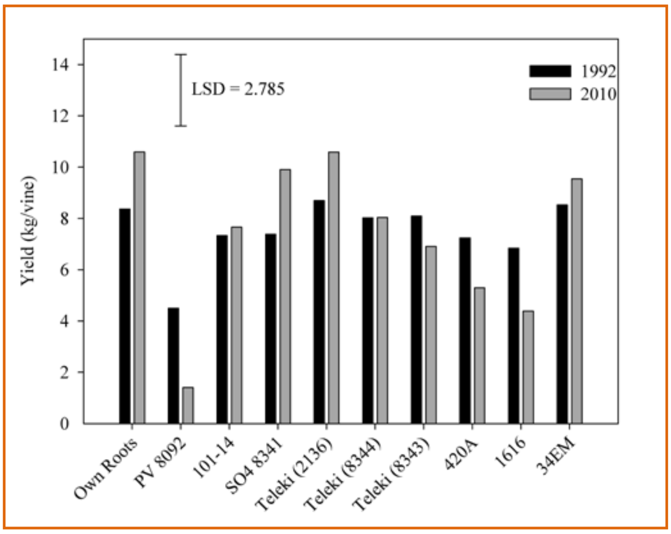


Figure 4. The effect of rootstock and vine age on yield of Shiraz vines.

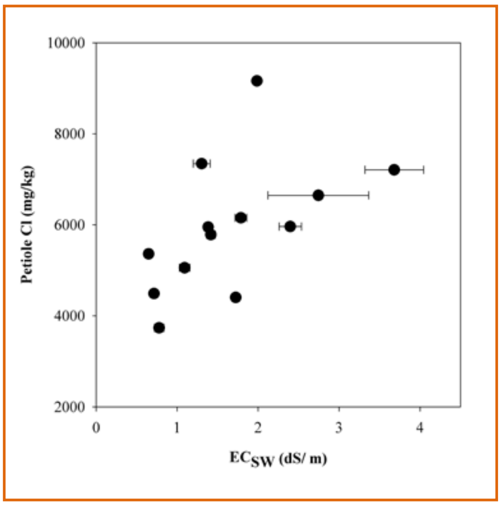
Linking vine tissue levels of sodium and chloride to soil salinity

In late winter of 2009, soil salinity monitoring sites were established in 14 vineyards across the Limestone Coast. Each site contained SoluSAMPLER™ soil water extractors at depths of 30 and 60 cm. The monitoring sites were located in vineyards which were planted to own rooted Cabernet Sauvignon vines, irrigated with drips and located on terra rossa soil or sandy loam soil over limestone.

Samplers at all sites except one, regularly yielded soil solutions during the spring of 2009. The salinity of these solutions were quantified by measuring their electrical conductivity (EC_{sw}). Grapevine leaf petioles were sampled in the last month of spring (bloom-time) and berries were sampled at harvest.

Figure 5a shows a correlation between bloom-time petiole chloride levels and the average EC_{sw} of soil water collected in spring (P=0.05). Petiole chloride levels were also shown to relate to chloride levels in berry juice at harvest (Figure 5b). Sodium levels in bloom-time petioles were not related to spring EC_{sw} although they did relate to berry juice sodium levels at harvest (P=0.002).

(a)



(b)

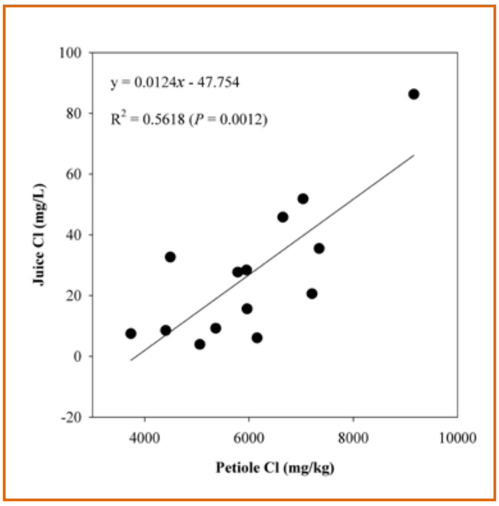


Figure 5. Bloom-time leaf petiole sodium and chloride concentrations plotted against average Spring soil water salinity (a) and relationship between bloom-time leaf petiole chloride levels and juice chloride levels at harvest (b).



Acknowledgements

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